The Relationship Between Surface Temperature Anomaly Time Series and those of OLR, Water Vapor, and Cloud Cover as Observed Using Nine Years of AIRS Version-5 Level-3 Products

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Sounder Research Team

NASA Sounder Science Team Meeting

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Outline

1. Comparison of AIRS and CERES anomaly time series of OLR and OLR_{CLR}

2. Explanation of recent decreases in global and tropical mean values of OLR

3. AIRS “Short-term” Longwave Cloud Radiative Feedback
   – A new product

Significance of AIRS OLR and OLR_{CLR}

AIRS OLR is a computed product for each AIRS FOR using an OLR RTA

Input data is AIRS retrieved T_{skin}, ε_{ν}, T(p), q(p), O_3(p), $\alpha\varepsilon$, and p_{cloud}

AIRS OLR_{CLR} is also computed for each AIRS FOR using same parameters but setting cloud fraction $\alpha\varepsilon = 0$. Roughly 70% of all cases pass OLR_{CLR} QC and are used to generate Level 3 OLR_{CLR} product

CERES products are derived from broad spectral band observations

Considered the "Gold Standard" of OLR and OLR_{CLR} data

CERES OLR_{CLR} represents CERES OLR values for scenes considered to be clear. Roughly 10% of all cases are used to generate Level 3 product

If Anomaly time series of AIRS OLR products closely match those of CERES

This validates anomaly time series of both AIRS and CERES OLR products

This indirectly validates anomaly time series of AIRS retrieved products

In addition, anomaly time series of OLR and OLR_{CLR} can now be attributed to those of their component parts

Comparison Data Sets

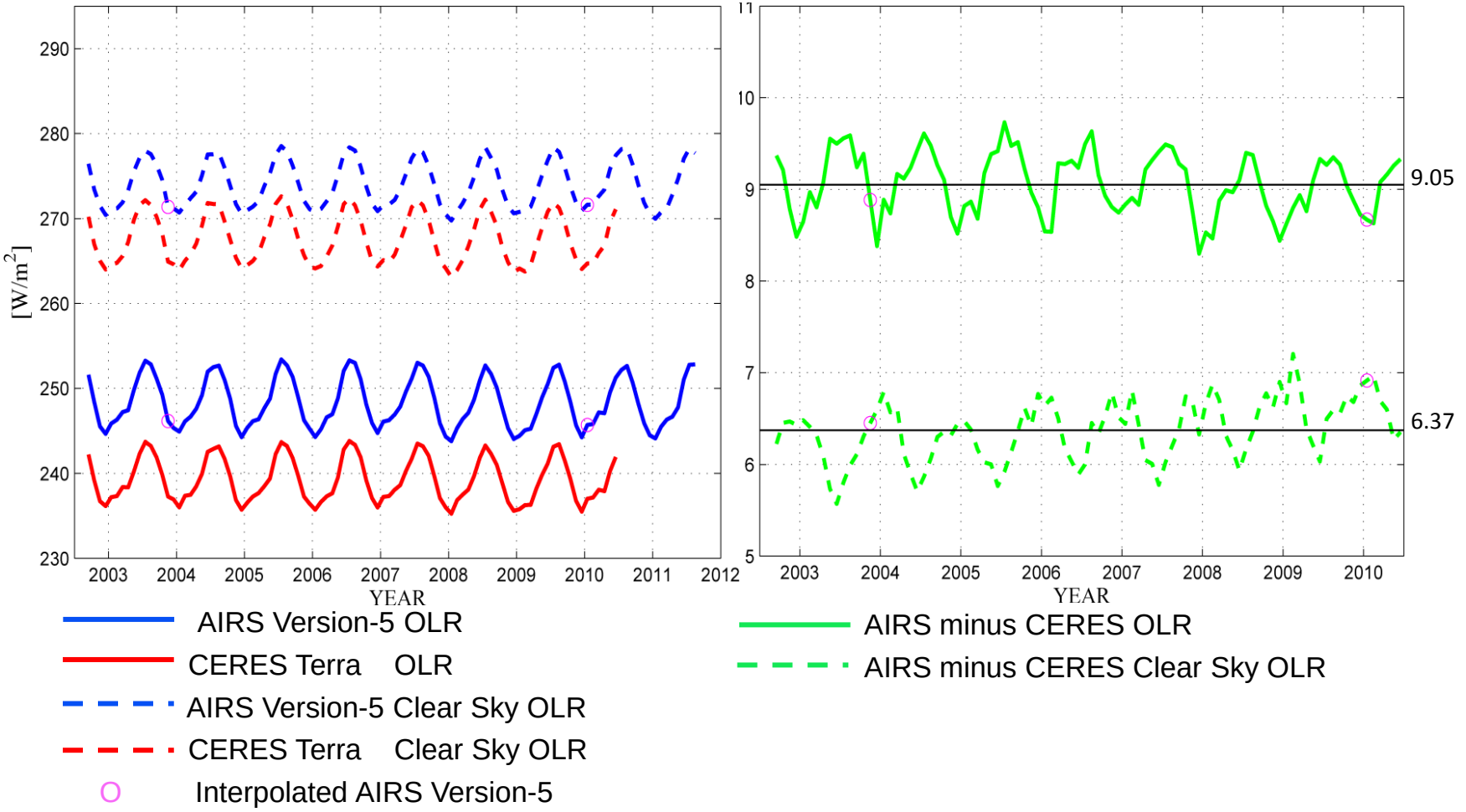
AIRS Science Team Version-5 monthly mean data obtained from Goddard DISC (Level 3)

- OLR, OLR_{CLR}, T_{skin}, q_{500}, cloud fraction
- Presented on a 1°x1° latitude-longitude grid
- 1:30 AM and 1:30 PM monthly mean values extracted separately and averaged together
- Data products extend to August 2011

CERES Science Team monthly mean data obtained from Langley ASDC

- All data presented on a 1°x1° latitude-longitude grid
  - Edition-2.5 CERES Terra OLR and OLR_{CLR}
  - Data products extend to June 2010
- We did not use Edition-2.5 CERES Aqua OLR and OLR_{CLR}
  - Data products extend only to August 2009

September 2002 through August 2011
Global Time Series (Watts/m^2)



AIRS Version-5 OLR and OLR_{CLR} are biased compared to CERES, with a small annual cycle

Definition of Anomalies and ARC's

Seven-year monthly climatologies were generated for each grid box by averaging data for seven Januaries, seven Februaries, ……

The monthly anomaly for each grid box is the difference of the monthly mean value for that month from its climatology

The Average Rate of Change (ARC) for a grid box is the slope of the straight line passing through the monthly anomaly time series

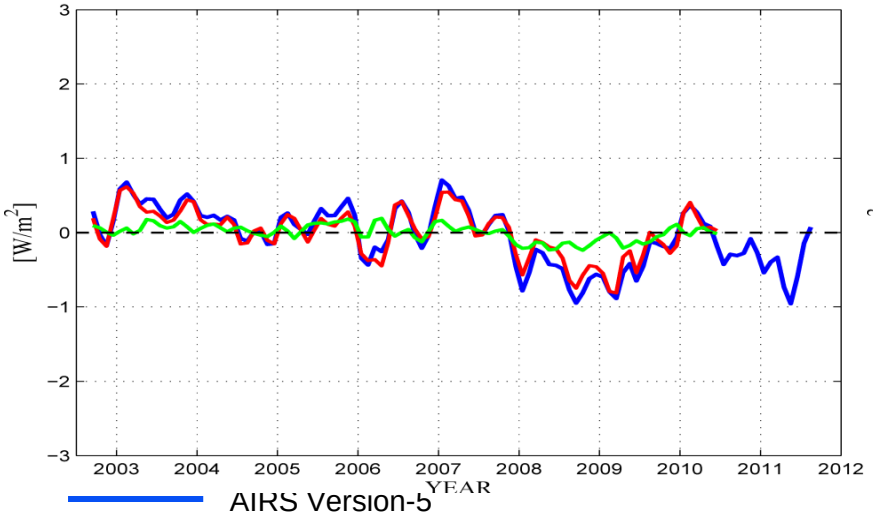
- Values of ARC's depend on the extent of the time series used
- Spatial patterns are more important than precise values

An area mean ARC is the cosine latitude weighted average ARC over the area

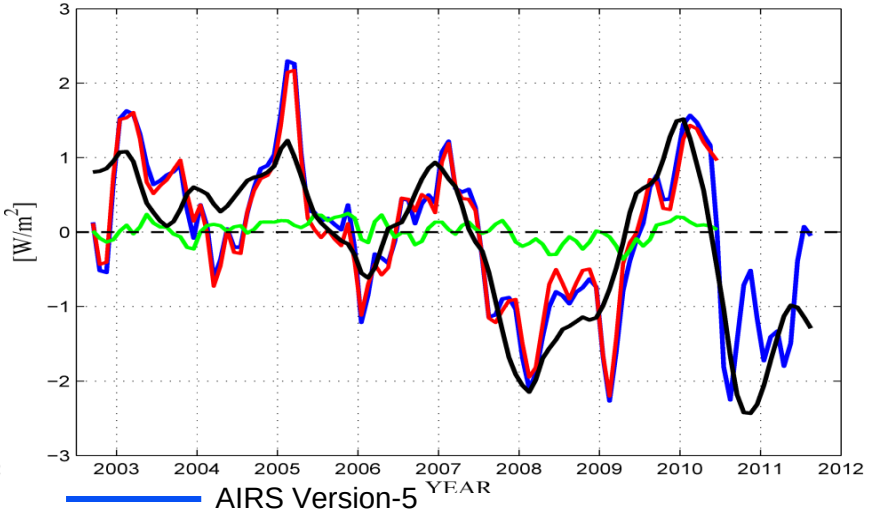
Monthly anomalies and ARC's of AIRS and CERES OLR can match well if there is a monthly bias between AIRS and CERES OLR but it is essentially constant in time.

September 2002 through August 2011 Anomaly Time Series

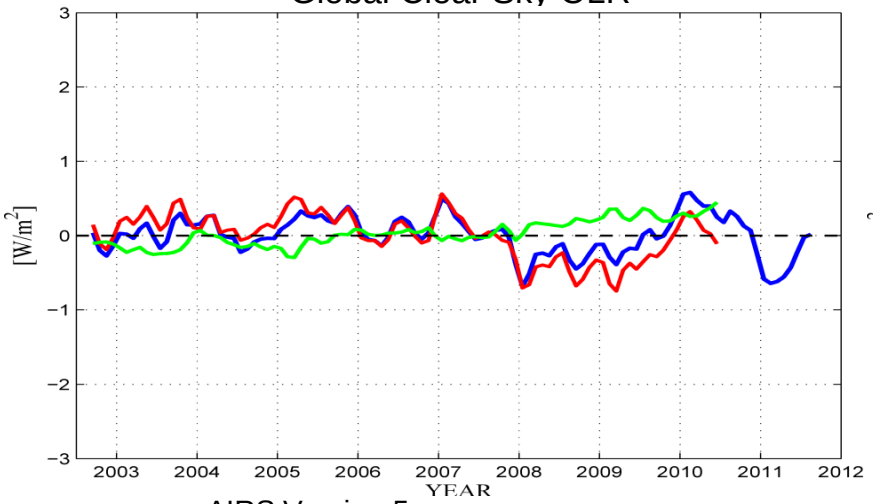
Global OLR



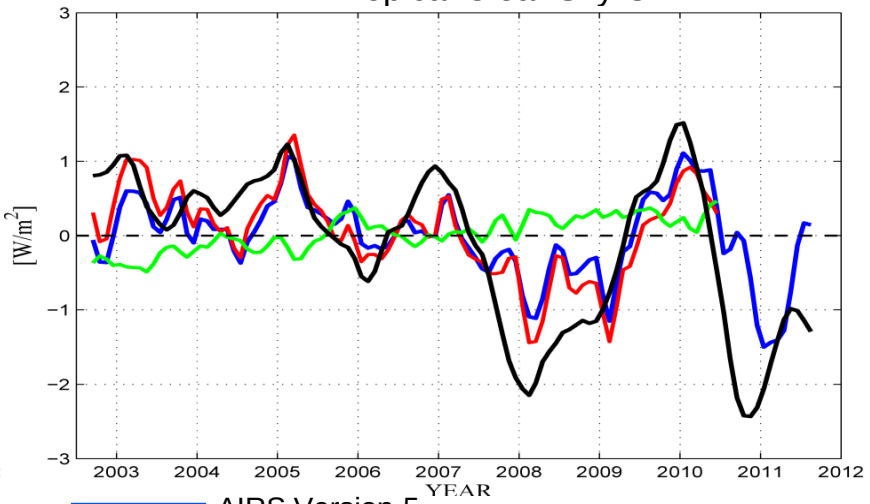
Tropical OLR



Global Clear Sky OLR



Tropical Clear Sky OLR



OLR Anomaly Time Series Comparison
September 2002 through June 2010

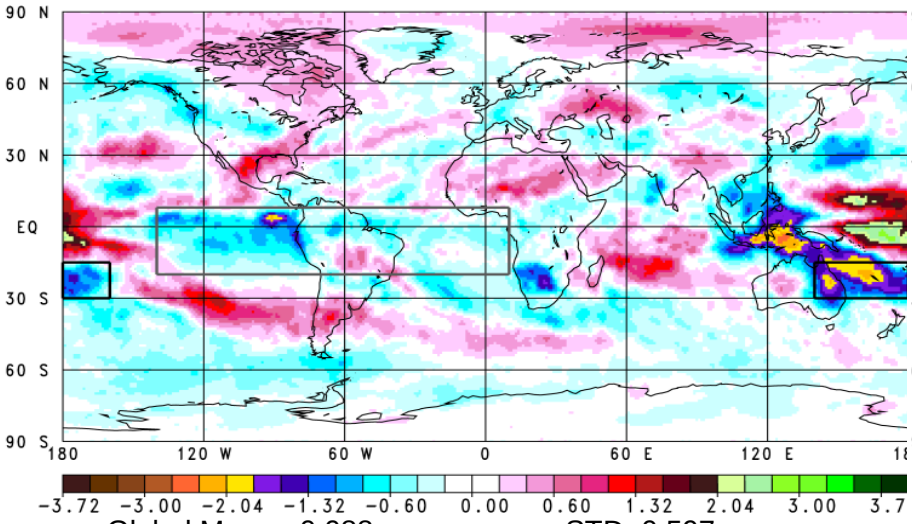
	Global	Tropical
AIRS ARC ($W/m^2/yr$)	−0.088 ± 0.015	−0.111 ± 0.043
CERES Terra ARC ($W/m^2/yr$)	−0.065 ± 0.013	−0.010 ± 0.040
AIRS Minus CERES STD (W/m^2)	0.108	0.139
AIRS/CERES Correlation	0.972	0.991

OLR_{CLR} Anomaly Time Series Comparison
September 2002 through June 2010

	Global	Tropical
AIRS ARC ($W/m^2/yr$)	−0.004 ± 0.011	−0.017 ± 0.023
CERES Terra ARC ($W/m^2/yr$)	−0.069 ± 0.012	−0.101 ± 0.025
AIRS Minus CERES STD (W/m^2)	0.175	0.235
AIRS/CERES Correlation	0.821	0.922

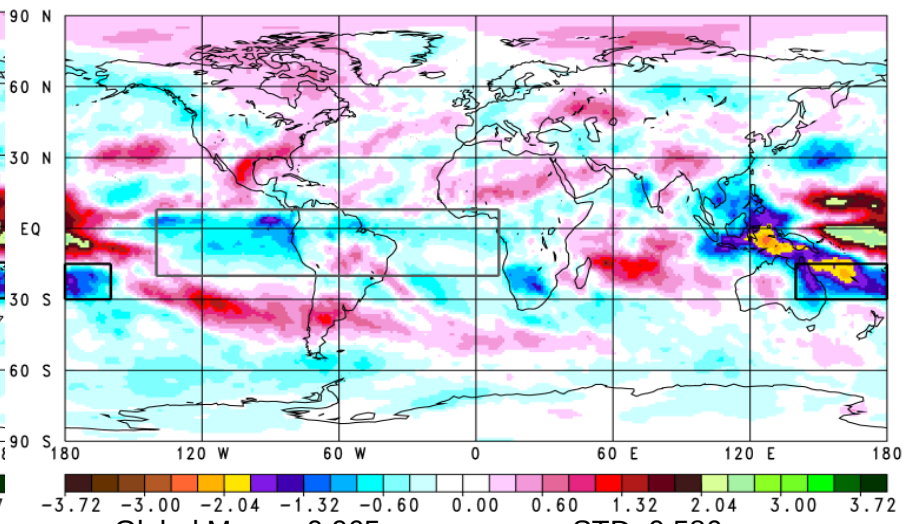
OLR Anomaly Average Rate of Change (Watts/m^2/yr)
September 2002 through June 2010

AIRS OLR



Global Mean=-0.088 STD=0.597

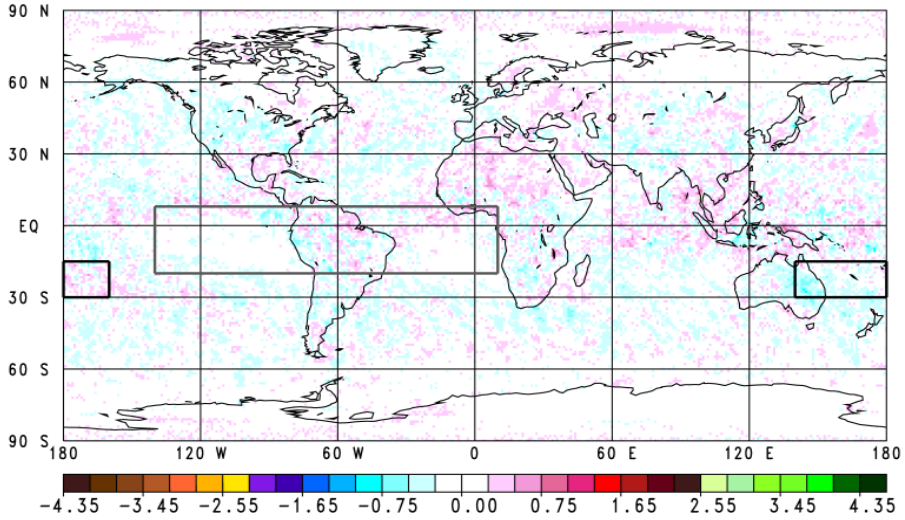
CERES OLR



Global Mean=-0.065 STD=0.586

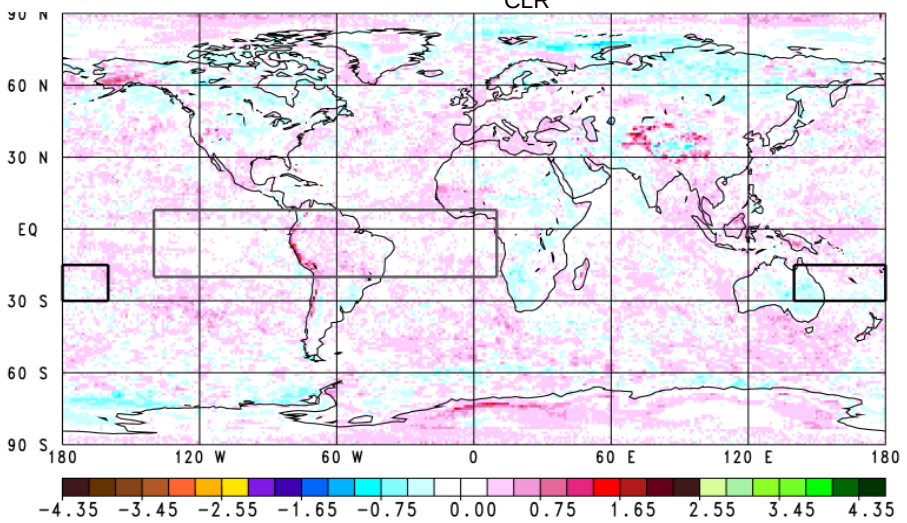
AIRS Version-5 minus CERES Editon-2.5

OLR



Global Mean=-0.023 STD=0.180 Correlation = 0.949

OLR_{CLR}



Global Mean= 0.065 STD=0.187 Correlation = 0.762

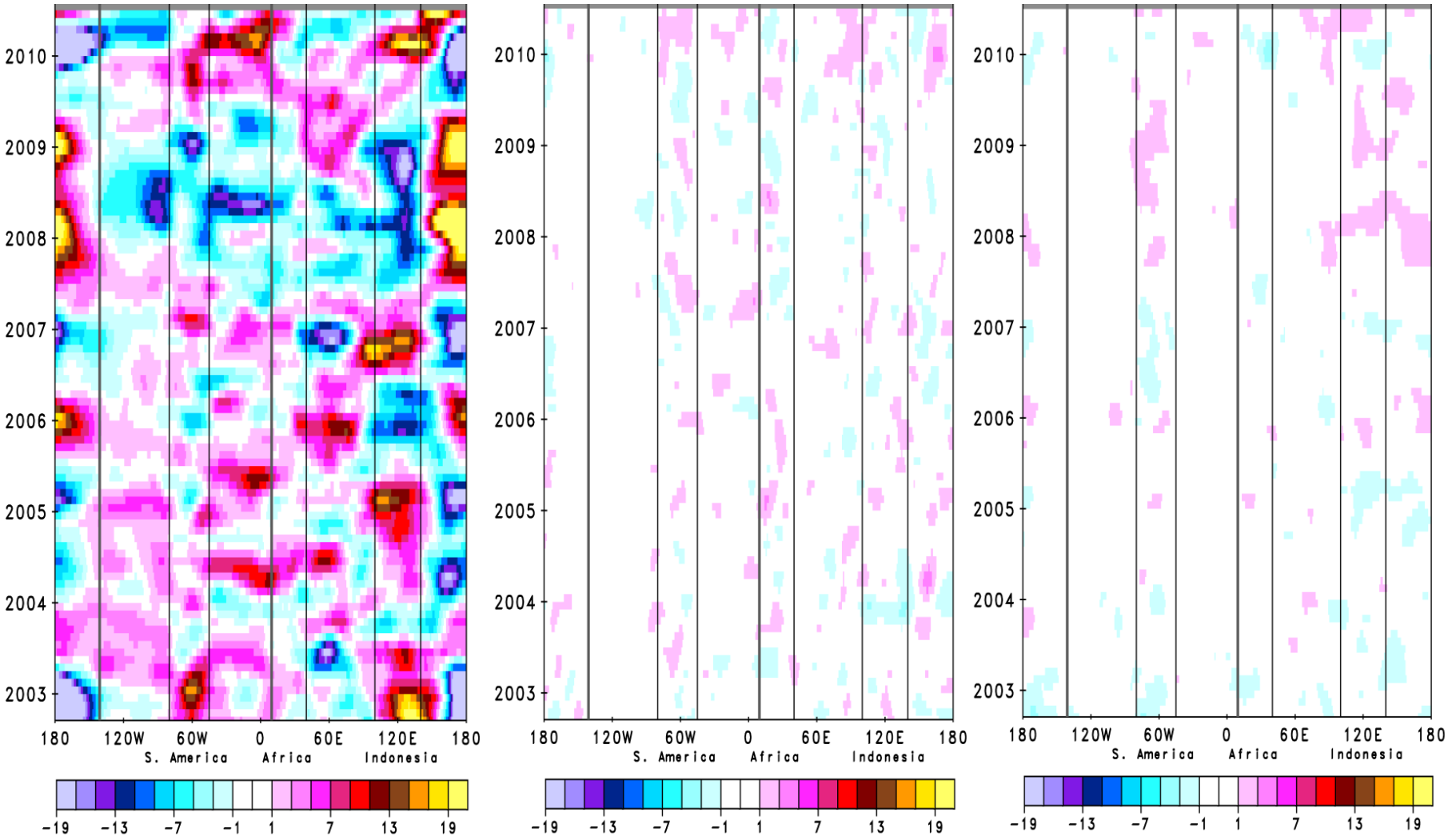
OLR Region 1 and 2 are enclosed by rectangles

OLR Anomaly (Watts/m^2) Tropics 5°N to 5°S
Monthlies, September 2002 through June 2010

CERES OLR

AIRS minus CERES OLR
Correlation = 0.993

AIRS minus CERES Clear Sky OLR
Correlation = 0.913



AIRS and CERES OLR Comparison Summary

AIRS and CERES OLR and OLR_{CLR} anomaly time series are in close agreement in space and time

- Agreement of AIRS and CERES OLR_{CLR} is remarkable given the sampling differences

Both show the period September 2002 through June 2010 was marked by a significant drop in Global mean and Tropical mean OLR on the order of -0.075 W/m^2/yr and -0.10 W/m^2/yr respectively

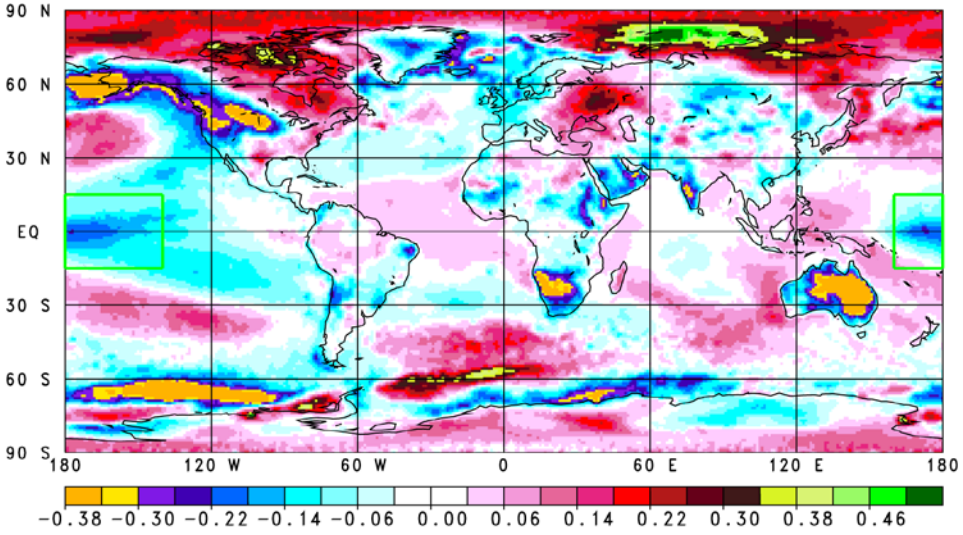
Both also show significant spatial structure of changes in OLR and $OLR_{CLR,}$ especially in the tropics

There is little question that these consistent findings are real

The next set of charts explain recent changes in OLR in terms of ARC's of AIRS derived products over the extended period September 2002 through August 2011

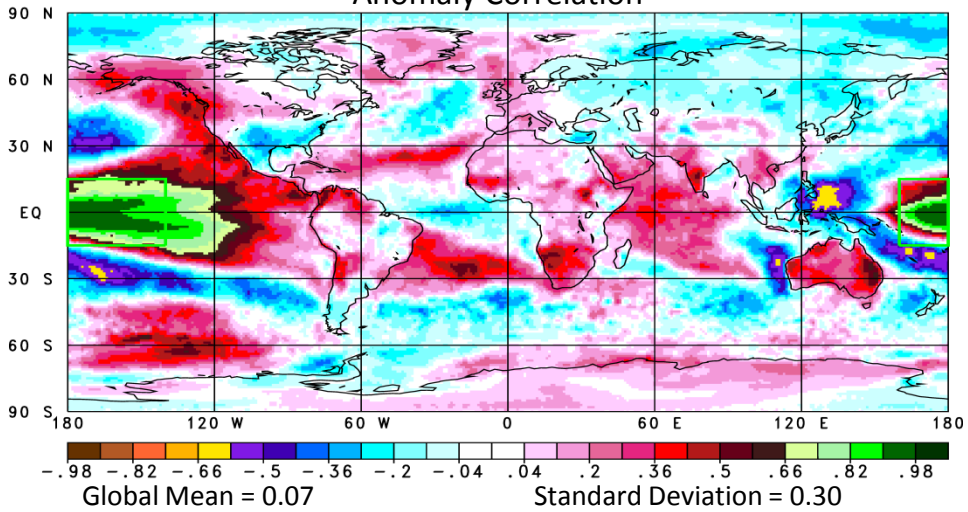
AIRS Version-5 Surface Skin Temperature Anomaly
September 2002 through August 2011

Average Rate of Change (K/yr)



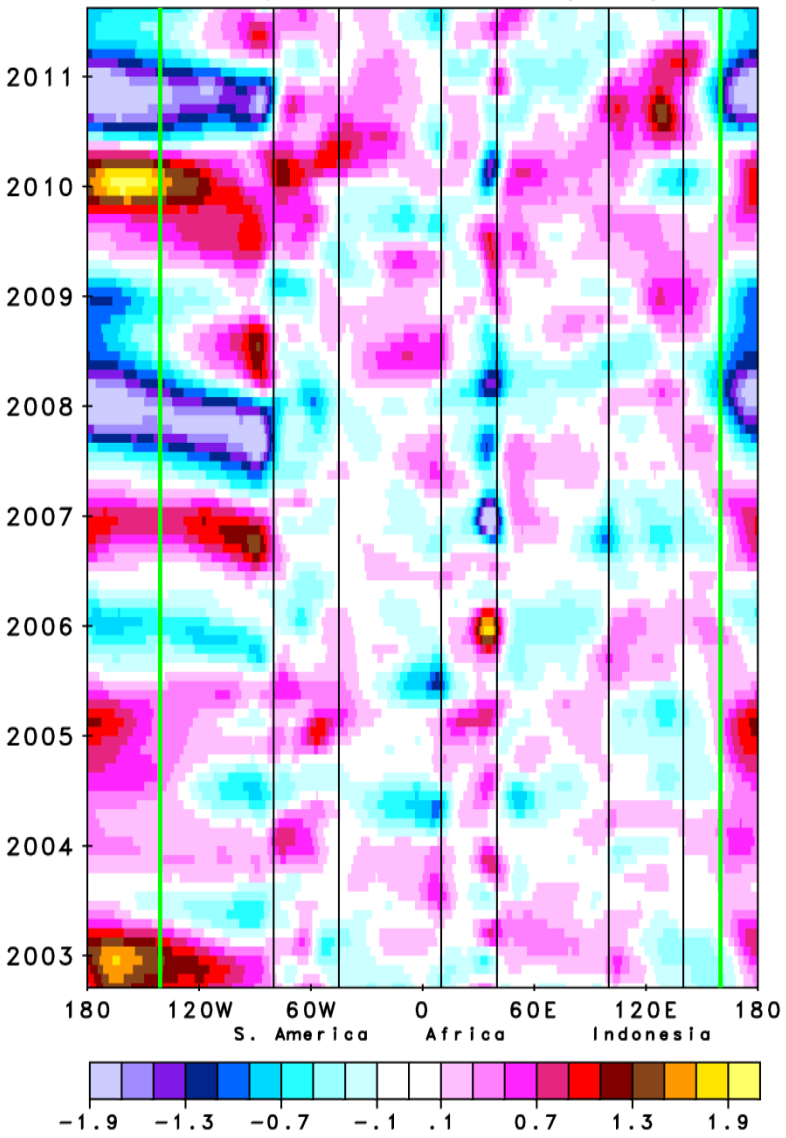
Global Mean = -0.01 Standard Deviation = 0.10

Surface Skin Temperature vs. El Niño Index
Anomaly Correlation



Global Mean = 0.07 Standard Deviation = 0.30

Tropics 5°N to 5°S (K) Monthly Anomalies



AIRS El Niño region is enclosed is the green rectangle: 15˚N-15˚S, 140˚W-160˚E

The AIRS El Niño index is the monthly mean SST anomaly averaged over this region.

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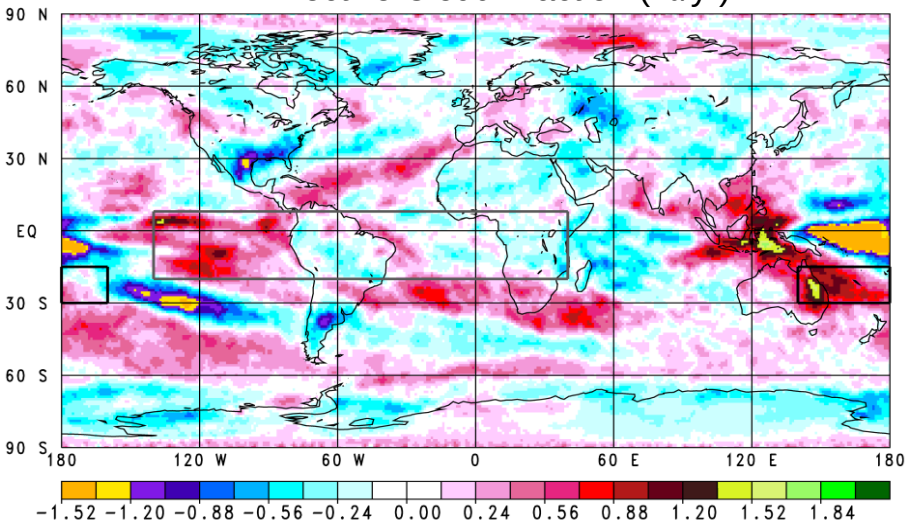
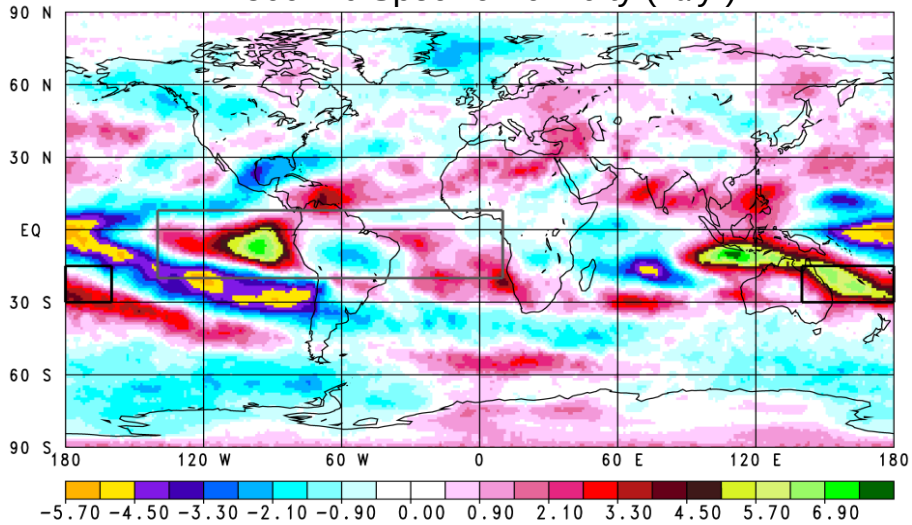
AIRS Version-5 Anomaly Average Rates of Change
September 2002 through August 2011

Effective Cloud Fraction (%/yr)



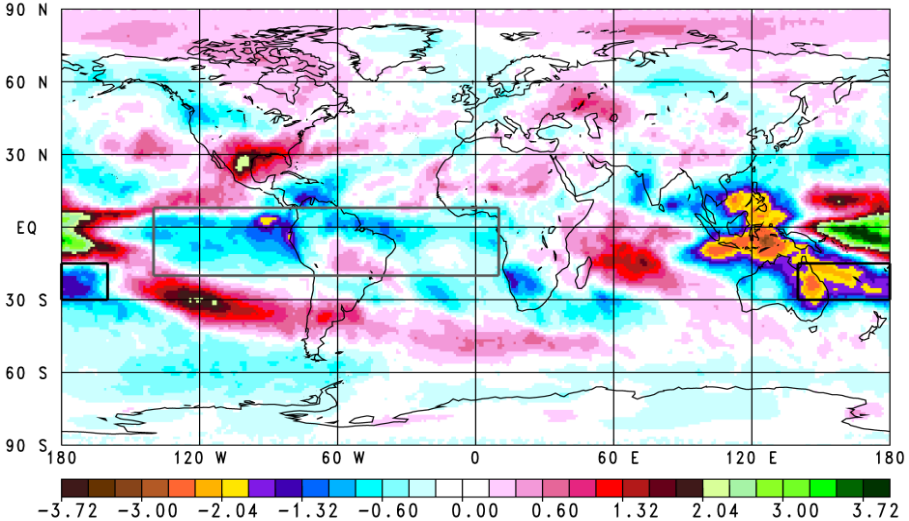
Global Mean=0.00 STD=0.43

500 mb Specific Humidity (%/yr)



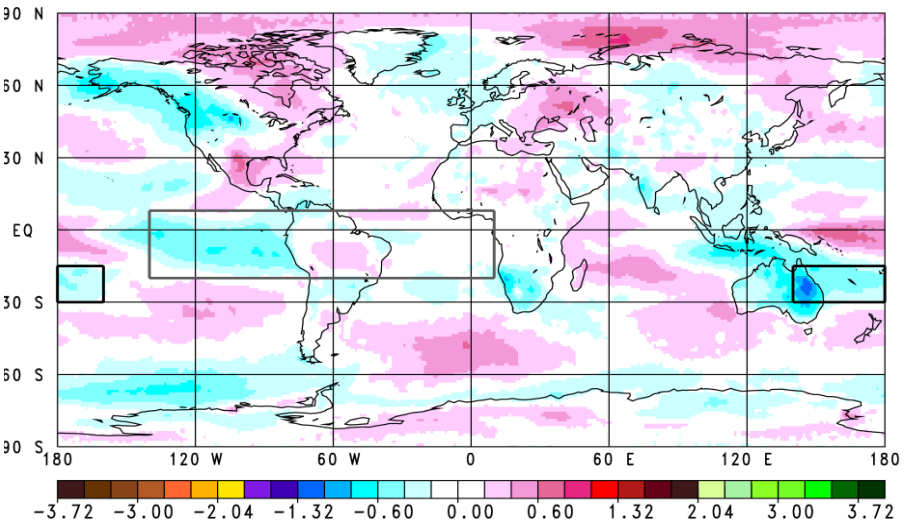
Global Mean=0.00 STD=1.95

OLR (Watts/m^2/yr)



Global Mean=-0.089 STD=0.786

Clear Sky OLR (Watts/m^2/yr)

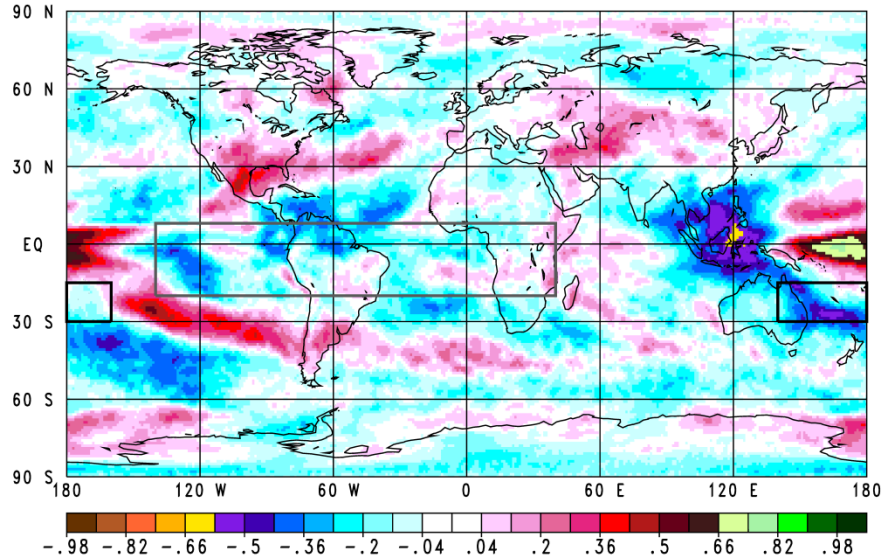


Global Mean=-0.019 STD=0.248

OLR Regions 1 and 2 are enclosed by rectangles.

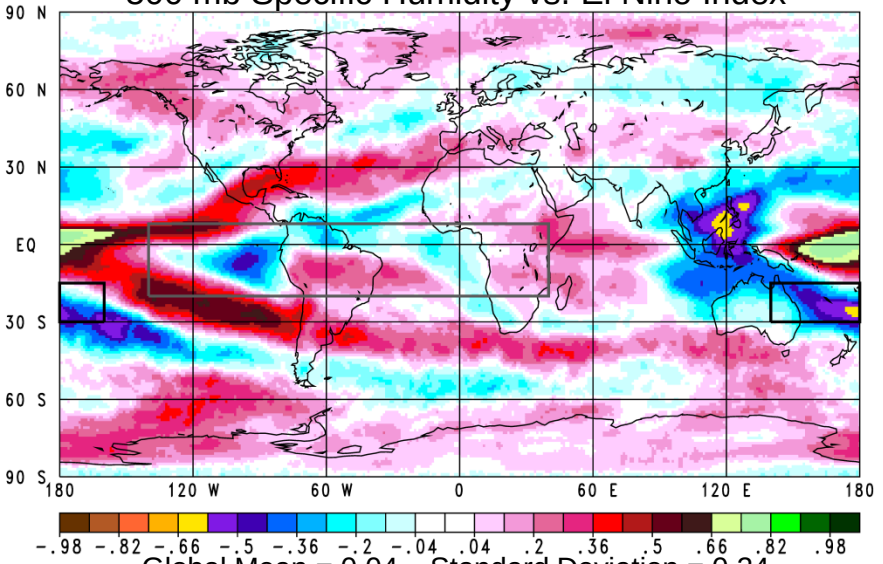
Anomaly Correlations September 2002 through August 2011

Effective Cloud Fraction vs. El Niño Index



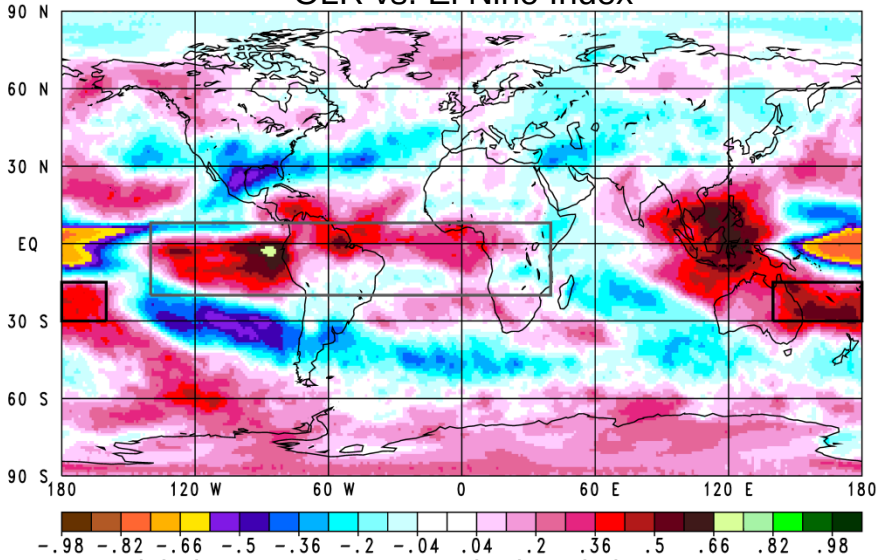
Global Mean = -0.06 Standard Deviation = 0.19

500 mb Specific Humidity vs. El Niño Index



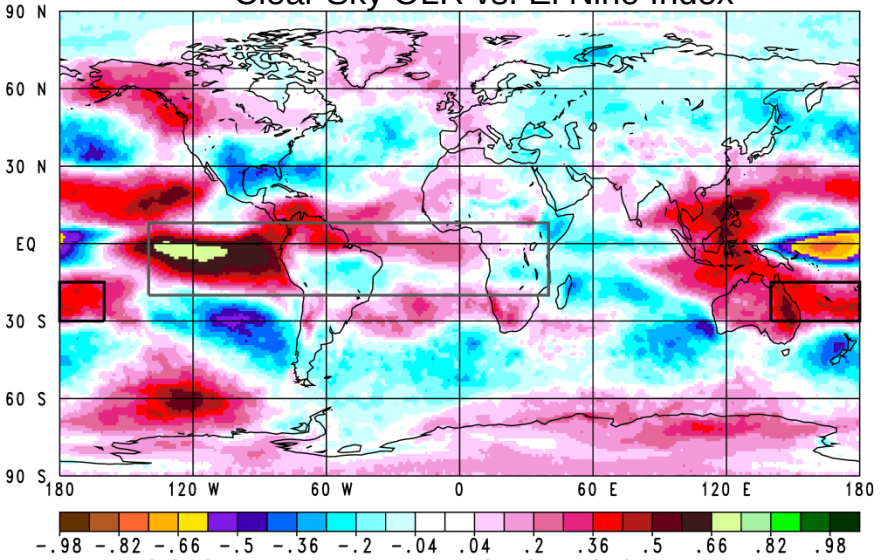
Global Mean = 0.04 Standard Deviation = 0.24

OLR vs. El Niño Index



Global Mean = 0.03 Standard Deviation = 0.25

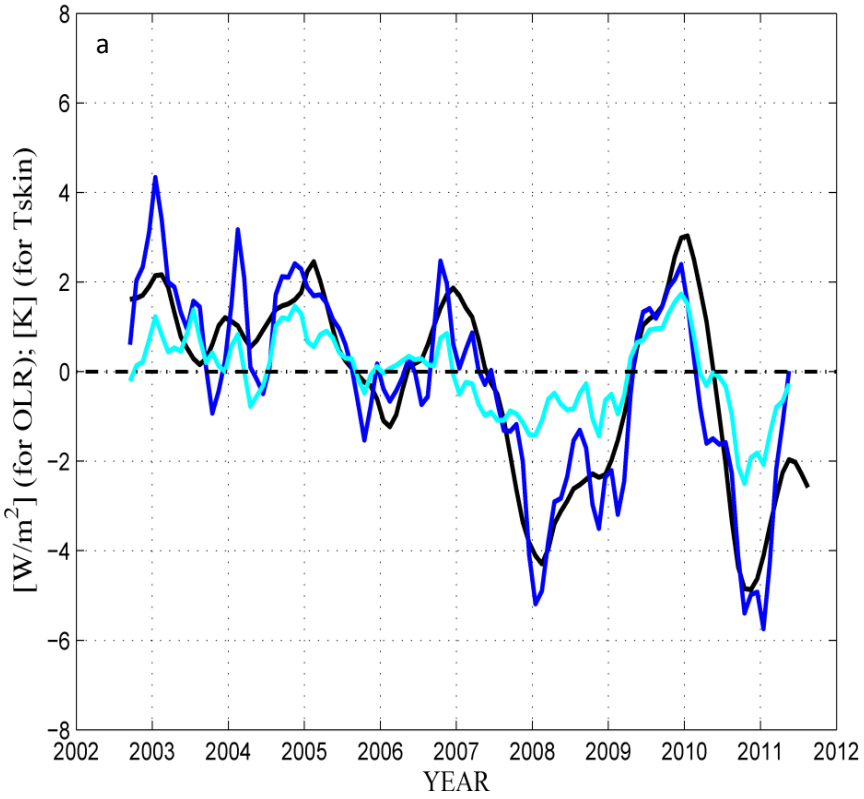
Clear Sky OLR vs. El Niño Index



Global Mean = 0.04 Standard Deviation = 0.24

AIRS Version-5 Regional Anomaly Time Series
September 2002 through August 2011

OLR Averaged over Region 1

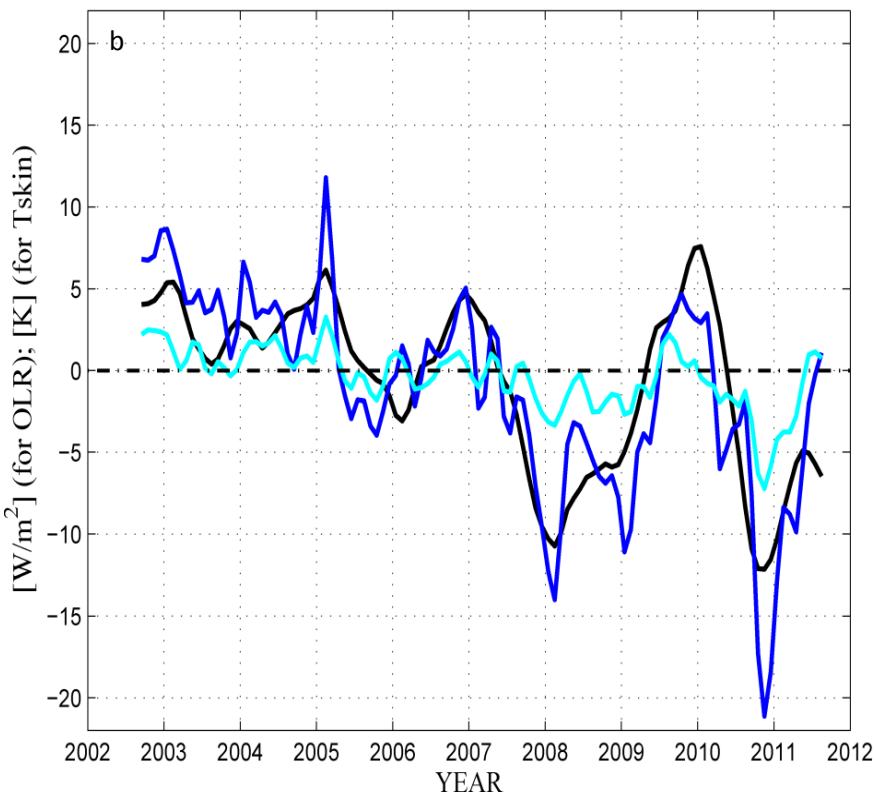


El Niño Index multiplied by 4

OLR lagged by 3 months

OLR_{CLR} lagged by 3 months

OLR Averaged over Region 2



El Niño Index multiplied by 10

OLR

OLR_{CLR}

Area Mean Average Rates of Change of OLR and OLR_{CLR} ($W/m^2/yr$) September 2002 through August 2011

Spatial Area	OLR ARC	OLRCLR ARC	OLR Anomaly Correlation with El Niño Index
Global	-0.089 ± 0.012	-0.019 ± 0.010	0.582
Tropical	-0.172 ± 0.034	-0.065 ± 0.020	0.807
Region1	-0.491 ± 0.064	-0.142 ± 0.030	0.755
Region 2	-1.486 ± 0.171	-0.435 ± 0.056	0.839
Global excluding Region 1	-0.039 ± 0.010	-0.005 ± 0.008	0.246
Tropical excluding Region 1	-0.028 ± 0.023	-0.023 ± 0.012	0.549
Global excluding Region 1 and 2	-0.010 ± 0.010	0.004 ± 0.008	-0.123
Tropical excluding Region 1 and 2	-0.001 ± 0.022	-0.014 ± 0.012	0.420

Anomalies in OLR Regions 1 and 2 are highly correlated with El Niño and account for the majority of the recent decreases in global and tropical mean OLR and OLR_{CLR} which result from a La Niña trend over the period under study

Longwave Cloud Radiative Feedback (F)

Longwave Cloud Radiative Feedback (F) refers to the relationship between anomalies of Longwave Cloud Radiative Forcing (LCRF) and T_{skin}

$$F = \Delta LCRF/\Delta T_{skin}$$

LCRF is the effect of cloud cover on OLR

$$LCRF = OLR_{CLR} - OLR$$

Understanding F is of great significance to climate prediction

Processes related to cloud feedbacks are the most uncertain components in global climate models

Computation of F

Following the approach of Andy Dessler, we evaluate F as the slope of the linear least squares fit to the scatter diagram of monthly mean anomalies of LCRF and T_{skin}. We compute $F_{i,j}$ for each grid point i,j

$F_{i,j}$ should not in principle be time period dependent because time is not one of the coordinates

We generated AIRS $F_{i,j}$ using 9 years of AIRS OLR, OLR_{CLR} and T_{skin} anomalies based on 9 year AIRS climatologies

We also generated TOVS $F_{i,j}$ based on 22 year TOVS Pathfinder anomalies based on 22 year TOVS climatologies

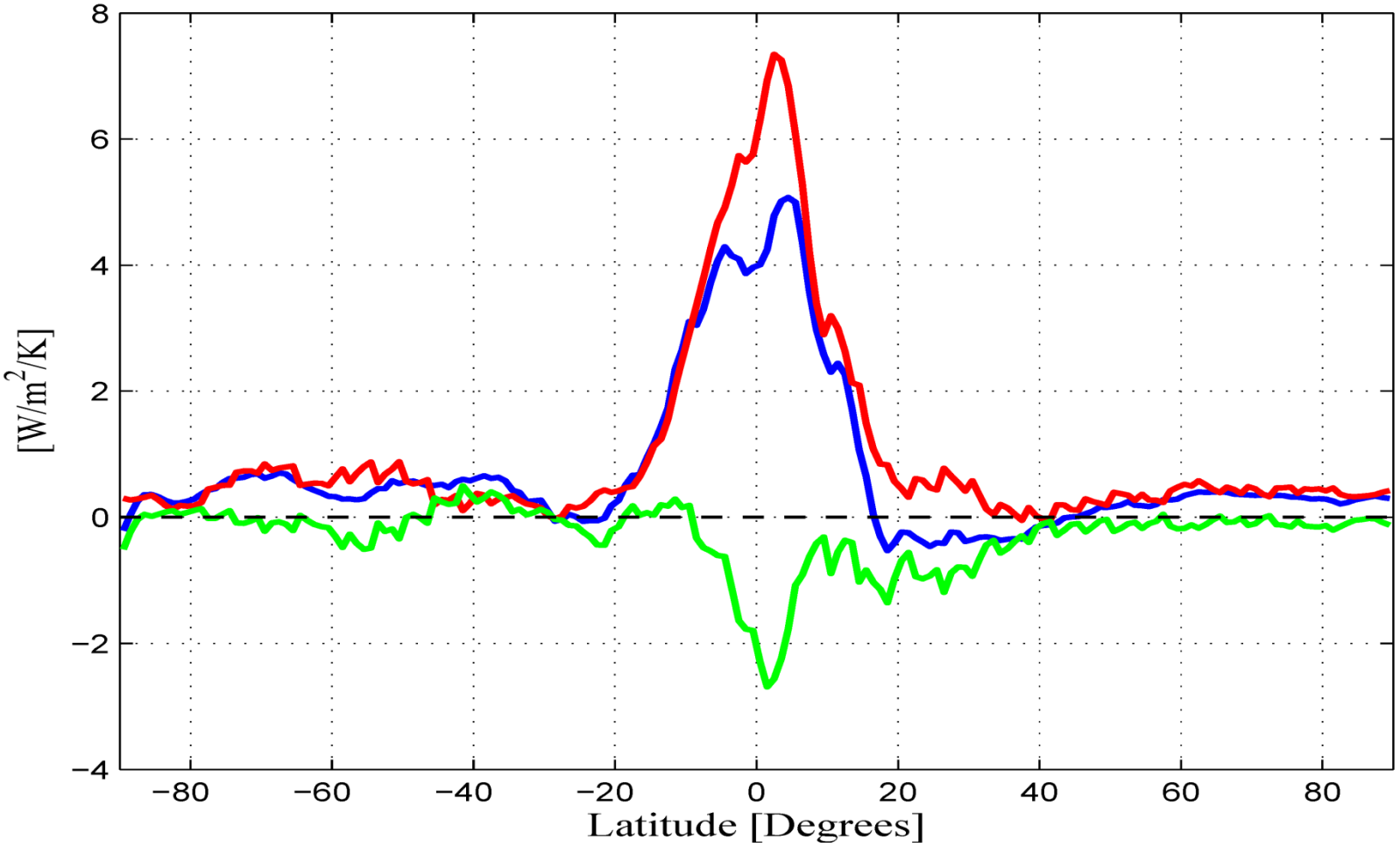
TOVS products come from many different satellites. All products are adjusted to a common time of day

AIRS F should be much more accurate than TOVS, but we wanted to see the extent that the two data sets agreed with each other

The agreement is remarkable and lends credence to $F_{i,j}$ derived from AIRS

Zonal Mean Longwave Cloud Radiative Feedback

Correlation = .96



AIRS Version-5 September 2002 through August 2011

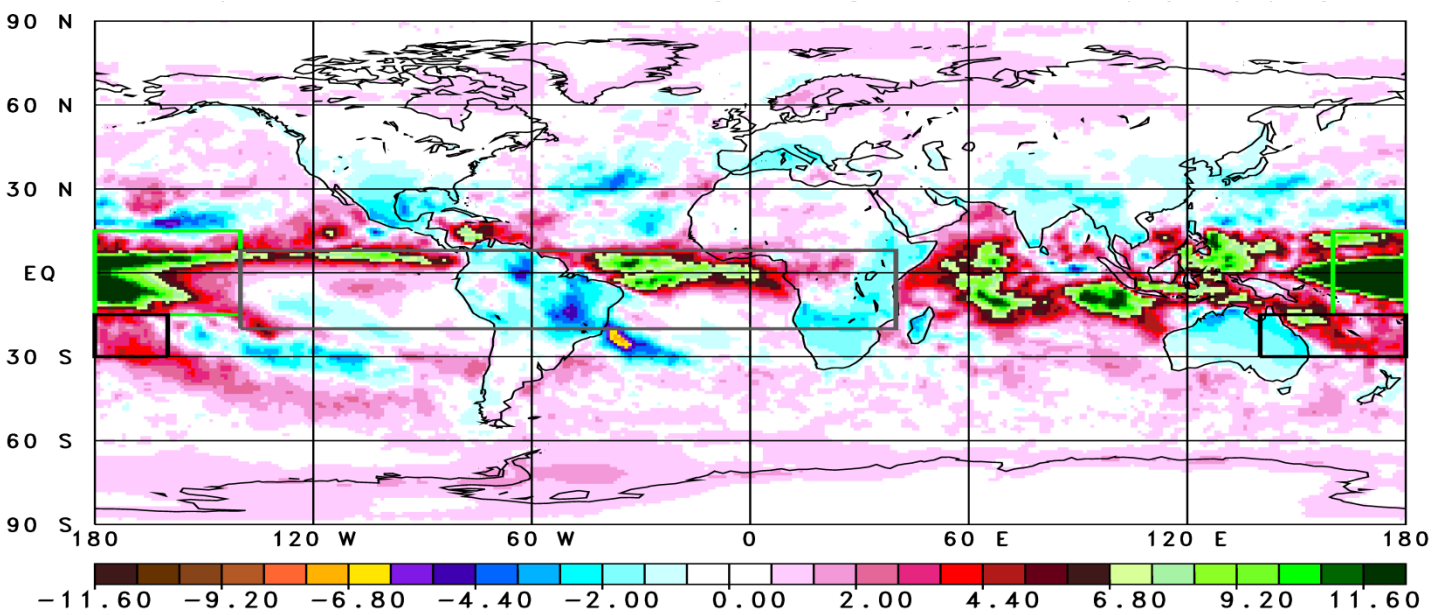
TOVS January 1980 through September 2002

AIRS minus TOVS Difference

AIRS Version-5

Longwave Cloud Radiative Feedback ($W/m^2/K$)

September 2002 through August 2011

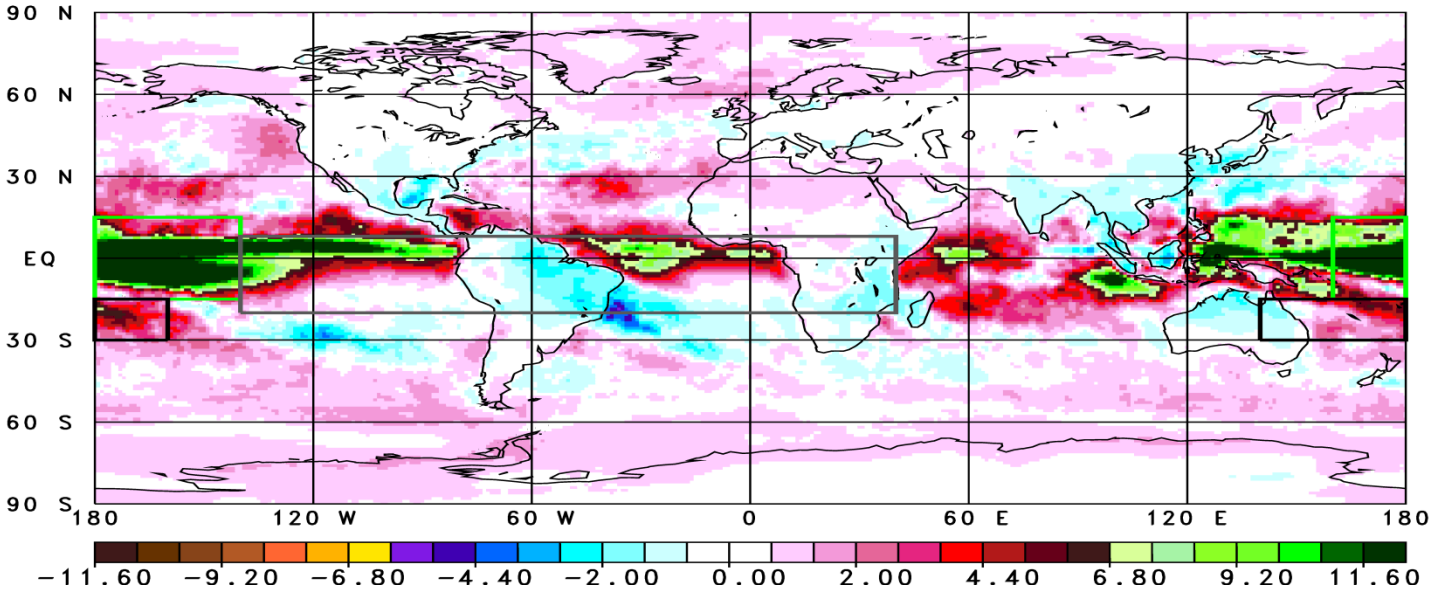


Global Mean = 0.98 Standard Deviation = 3.02

TOVS

Longwave Cloud Radiative Feedback ($W/m^2/K$)

January 1980 through February 2002



Global Mean = 1.38 Standard Deviation = 3.46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